Analysis, Design and Performance Evaluation of Negative output Triple-Lift Luo Converter

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***Abstract*— the voltage lift technique is a popular method widely applied in electronic circuit design. Since the effect of parasitic elements limits the output voltage and power transfer efficiency of DC-DC converters, the voltage lift technique improve circuit characteristics. This technique has been successfully applied for DC-DC converters resulting Luo converters. Negative output Triple-Lift Luo converters are another series of new DC-DC step-up (boost) converters, which were developed from elementary Luo converter using the voltage lift technique. Triple-Lift Luo circuit is derived from negative output elementary Luo converter by adding the lift circuit three times. These converters perform positive to negative DC-DC voltage-increasing conversion with high power density, high efficiency and cheap topology in simple structure. They are different from other existing DC-DC step-up converters and possess many advantages, including a high output voltage with small ripples. Therefore, these converters will be widely used in computer peripheral circuits and industrial applications, especially for high output voltage projects. Attempts are being made to enhance the performance of DC-DC converters by soft computing techniques such as fuzzy logic (FL) and neural network techniques. The main disadvantage of the fuzzy control system is the heavy computation burden of translating the linguistic control rules into corresponding control actions. Neural network has the property of generalization and the control surface of the neural controller is smooth. This research work attempts to develop ANN controller for closed loop control of DC-DC Luo power converter. Training data obtained from the simulation of a fuzzy controller. The performance of the controller is studied for various operating conditions, such as step change in supply voltage and step change in load. The parameters selected are steady-state error, peak overshoot and settling time**

Keywords-Triple-Lift Luo converter; neural network;fuzzy logic

Introduction

Switched-mode DC-DC converters are made up of power semiconductor devices which are operated as electronic switches referred to as Switched mode power supply (SMPS). DC-DC converter is very popular because of its high efficiency and compact size[1-2]. PWM is the most widely used duty ratio control method where switching frequency is constant and the duty cycle, varies with the load resistance variations at the Nth sampling time. The output of the designed controller is the change in duty cycle. Then, the duty cycle is determined by adding the previous duty cycle to the change in duty cycle. This duty cycle signal is then sent to a PWM output stage that generates the appropriate switching pattern for the switching power supplies.

The selection of the controller parameters in the PI controller is a compromise between robustness and transient response. There have been many approaches proposed for PWM switching control design based on the sliding-mode control, fuzzy control and adaptive neural control techniques. In the sliding-mode control design for DC-DC converters, the controllers are simple to design and easy to implement. However, their performances normally depend on the operating point. Thus the design of control parameters in all operating conditions is difficult. In the fuzzy control design for DC-DC converters, the fuzzy rule is developed through trial-and-error to achieve satisfactory performances. This is time consuming. Even though the usage of tuning algorithm provided satisfactory regulator performance, the computation loading of these learning algorithms is too complex[3]. The key point of neural- network-based control technique is its approximation ability in which it can approximate an unknown system dynamics or an ideal controller after learning. Based on this property, ANN controllers have been developed to compensate for the effects of nonlinearities and system uncertainties, so that the stability, convergence and robustness of the control system can be improved[4-6].

Analysis of Negative Output Triple-Lift Luo Converter

The elementary circuit can perform step-down and step-up DC-DC conversion. The other negative output Luo converters are derived from this elementary circuit; they are the self-lift circuit, re-lift circuit and multiple lift circuits (e.g. triple-lift and quadruple-lift circuits). The negative output triple-lift circuit is shown in Fig.1. Switch S is a p-channel power MOSFET device (PMOS). It is driven by a pulse width modulated (PWM) switching signal with repeating frequency f and conduction duty k. The switch repeating period is $T = 1/f$ so that the switch-on period is kT and the switch-off period is $(1 - k)T$. The load is usually resistive, i.e., $R = V_o/Z_o$; the normalised load is $Z_n=R/fL$. Each converter consists of a pump circuit S-L-D-(C) and a ΙΙ-type filter C-L_o-C_o, as well as a lift circuit. The pump inductor L absorbs energy from the source during switch-on, and transfers the stored energy to capacitor C during switch-off. The energy on capacitor C is then delivered to the load during switch-on. Therefore, if the voltage V, is high, the output voltage V_o is correspondingly high. When the switch S is turned off, the current i_o flows through the freewheeling diode D. This current descends in a whole switching-off period (1 - k)T. If the current i_o does not reach zero before switch S is turned on again, this working state is defined as a continuous mode. If the current i_o reaches zero before switch S is turned on again, this working state is defined as a discontinuous mode.

Triple-Lift Circuit consists of one static switch S, four inductors L, L_1, L2 and Lo, five capacitors C, C_l, C_2, C_3 and C_O, and diodes. The circuit C_1-D_1-L_l-C_2-D_2-D_{11}-L_2-C_3-D_3-$D_{12}$is the lift circuit. Capacitors C_1, C_2 and C_3perform characteristics to lift the capacitor voltage V_c by three times the source voltage V_I, L_1 and L_2 perform the function of ladder joints to link the three capacitors C_1,C_2 and C_3 and raise the capacitor voltage V_c. The currents $i_{C1}(t)$, $i_{c2}(t)$ and $i_{C3}(t)$ are exponential functions. They have large values at the moment of power-on, but they are small, because $V_{C1} = V_{C2} = Vc_3= V_I$ in the steady state.

The output voltage and current are

$$V_0 = \frac{3}{1-k} V_I \tag{1}$$

$$I_0 = \frac{3}{1-k} I_I \tag{2}$$

The voltage transfer gain in continuous mode is

$$M_T = {V_0}/{V_I} = \frac{3}{1-k} \tag{3}$$

Other average voltages:

$$V_c = V_0 \; ; V_{C1} = V_{C2}=V_{C3} =V_I \tag{4}$$

Other average currents:

$$I_{L0} = I_0 \; ;$$

$$I_L = I_{L1} = I_{L2} = \frac{1}{1-k} I_0 \tag{5}$$

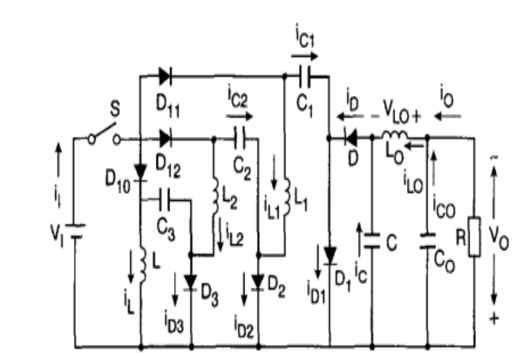

Figure 1 Negative Output Triple-Lift Luo converter

TABLE I. **CIRCUIT PARAMETERS OF TRIPLE –LIFT LUO CONVERTER**

Sl.No	*Parameters*	*Symbol*	*Values*
1	Input voltage	V_{in}	10 V
2	Output voltage	V_o	-60V
3	Inductors	L-L_1-L_2-L_0	100µH
4	Capacitors	C_0-C1-C2-C3-C	5µf
5	Load resistance	R	10Ω
6	Switching frequency	f_s	50KHZ
7	Duty ratio	D	0.5

Artificial Neural Network (ANN)

The artificial neural network is an information-processing system that has certain performance characteristics in common with biological neural networks. Artificial neural networks have been developed as generalizations of mathematical models of human cognition or neural biology, based on the assumptions that Information processing occurs at many simple elements called neurons. Signals are passed between neurons over connection links. Each connection link has an associated weight, which multiplies the signal transmitted to obtained net input. Each neuron applies an activation function (usually nonlinear) to its net input (sum of weighted input signals) to determine its output signal.

A neural network is characterized by (1) its pattern of connections between the neurons (called its architecture), (2) its method of determining the weights on the connections (called its training, or learning, algorithm), and (3) its activation function. A neural net consists of a large number of simple processing elements called neurons, units, cells, or nodes. Each neuron is connected to other neurons by means of directed communication links, each with an associated weight. The weights represent information being used by the net to solve a problem.

Consider a neuron Y, illustrated in Fig. 2 , that receives inputs from neurons X_I, X_2 , and X_3 . The weights on the connections from X_I, X_2, and X_3 to neuron Y are W_1 , W_2, and W_3, respectively. The net input, Y_{in}, to neuron Y is the sum of the weighted signals

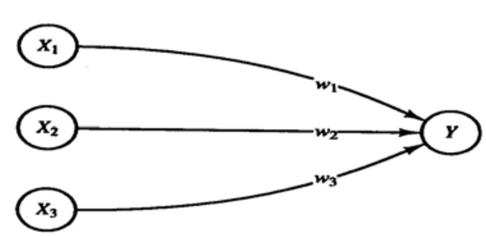

Figure 1 Single Layer Neural Network

As shown in Figure 3 the activation y of neuron Y is given by some function of its net input, $y = f(y_{in})$, e.g., the logistic sigmoid function (an S-shaped curve) which is given by

$$f(y_{in}) = \frac{1}{1+e^{-y_{in}}} \tag{5}$$

or any other activation functions. For a single layer net, the weights for one output unit do not influence the weights for other output units. A multilayer net is a net with one or more layers (or levels) of nodes (the so called hidden units) between the input units and the output units. Typically, there is a layer of weights between two adjacent levels of units (input, hidden, or output). Multilayer nets can solve more complicated problems than can single-layer nets

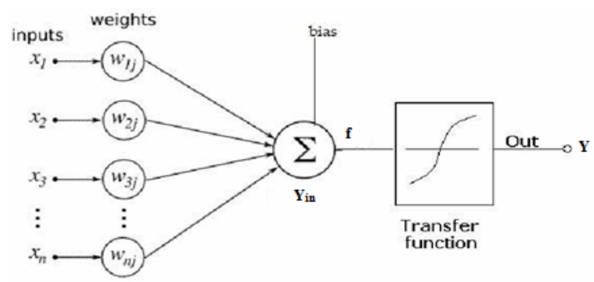

Figure 3 Structure of an elementary neuron

ANN based Triple-Lift Luo converter

The input-output data necessary for the off-line training of the neural network have been obtained in the present work from the simulated fuzzy controller. The data set is made sufficiently rich to ensure stable operation since no additional learning will take place after training. A back-propagation algorithm is used for training of the created network. The LEARNGDM function which has a gradient descent with momentum weight / bias learning is used in this work. Learning occurs according to the learning parameters: learning rate=0.01 and momentum constant t = 0.9.

MSE is the performance criteria used in this work that evaluates the network according to the mean of the square of the error between the target and computed output. The minimum MSE that can be achieved in this work is 1e-7.

For a back-propagation training algorithm, the derivative of the activation function is needed. Therefore, the activation function selected must be differentiable. The sigmoid function satisfies this requirement and it is the commonly used soft-limiting activation function. It is also quite common to use linear output nodes to make learning easier and using a linear activation function in the output layer does not 'squash' the range of output. Hence, a bipolar sigmoid activation function and a linear activation function are used for the hidden and output layers, respectively. Trials have been carried out to obtain maximum accuracy with a minimum number of neurons per layer. The feed forward neural network developed consists of two neurons in the input layer, fifteen neurons in the hidden layer and one neuron in the output layer. The input to the neuro controller is voltage error(e) and change in the voltage error.. The output of the controller is the corrected duty ratio (dk).The weights of the network are trained off-line for each architecture. The conventional approach to control the output voltage of a DC-DC converter is to modulate the duty cycle of gate control signals in a switching network. In this research, a multi-layer feed-forward artificial neural network is employed to achieve real-time adaptive control. It is well known that a back propagation neural network which is a multi-layer feed-forward neural network. An appropriate size of neural network can approximate any nonlinear function to a desired accuracy after it is fully trained.

Simulation Results

Initially a MATLAB –Simulink model of the Luo converter is developed and simulated fuzzy controller is designed and closed loop operation is simulated .From the designed fuzzy controller training patterns are generated and used to train the ANN to be used as a controller. The neuro controller was trained using neural network toolbox with the patterns obtained from the fuzzy controller. The closed loop operations are simulated with the trained neural network and performance is studied.

The simulated graphs of ANN controller are given in Figure 4 & 5. A step change in supply voltage from 10 to 12.5volts is applied at 3.5msec and step change of 10 to 7.5volts at 7msec with R=10Ω. It is observed that when the input voltage is changed from 10-12.5volts the settling time is 4ms and peak overshoot is 4.16% and when the input voltage is changed from 10V-7.5V the settling time is 2ms and the peak overshoot 2.5% under line disturbances. A step change in load from 10 to 12Ω is applied at 3.5msec and step change in load 10 to 8 Ω at 7msec. It is observed that the settling time is 2ms and peak overshoot is 3.33% for a step change of 10Ω to 12Ω and the settling time is 2.5ms and the peak overshoot 3.33% for a step change of 10Ω- 8Ω under load disturbances

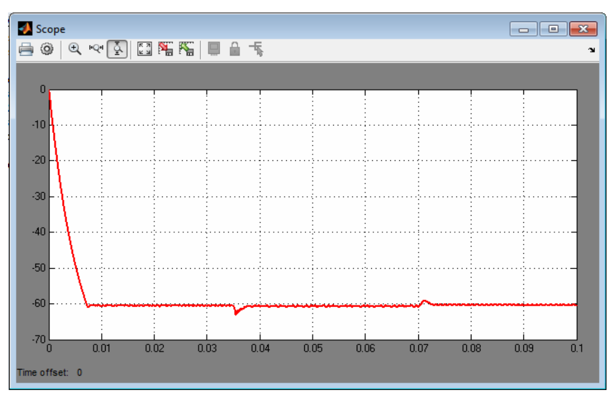

Figure 4 Closed loop response of Triple-Lift Luo converter with sudden disturbances of at 3.5msec & 7msec ± 25% of rated supply

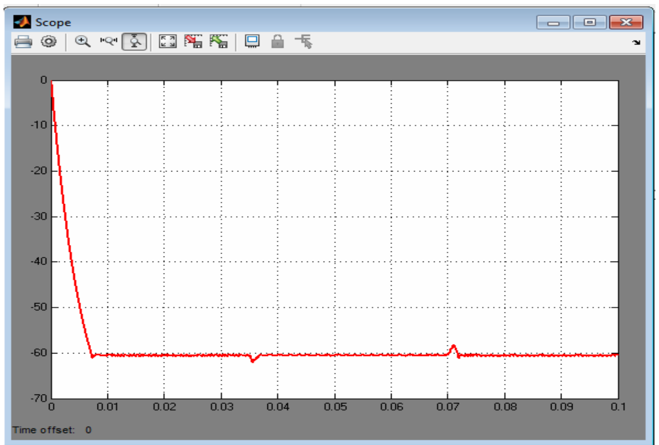

Figure 5 Closed loop response of Triple-Lift Luo converter with sudden disturbances of 3.5msec & 7msec ± 20% of rated Load

Conclusion

In DC-DC converter applications, it is desired to obtain a constant output voltage inspite of disturbances in input supply and load. A neural network controller for a Luo converter is designed control is achieved under various input and load conditions and the neural network controller gives a better performance in terms of both line regulation and load regulation. Simulation results are satisfactory in terms of stability. It can be shown that higher dynamic and adaptable regulation can be obtained.

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